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science for a changing world

nehrp

Innovations in Earthquake Monitoring, Risk Assessment, and Preparation

David Applegate
U.S. Geological Survey

April 22, 2011

Statuatory Roles and Responsibilities

- USGS has the delegated federal responsibility to provide notifications and warnings for earthquakes, volcanic eruptions, and landslides.
- USGS seismic networks support NOAA's tsunami warnings.
- USGS streamgages and storm surge monitors support NOAA's flood and severe weather (including hurricane) warnings.
- USGS geomagnetic observatories support NOAA and AFWA geomagnetic storm forecasts.
- USGS geospatial information supports response operations for wildfire and many other disasters.

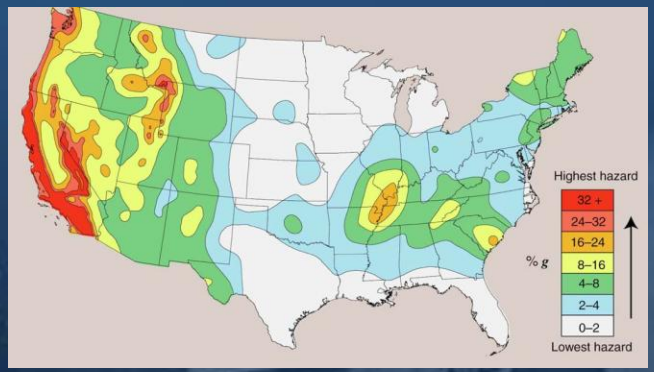
USGS

The mandate of the National Earthquake Hazard Reduction Program

- Develop effective measures for earthquake loss reduction;
- Promote their adoption;
- Improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines.

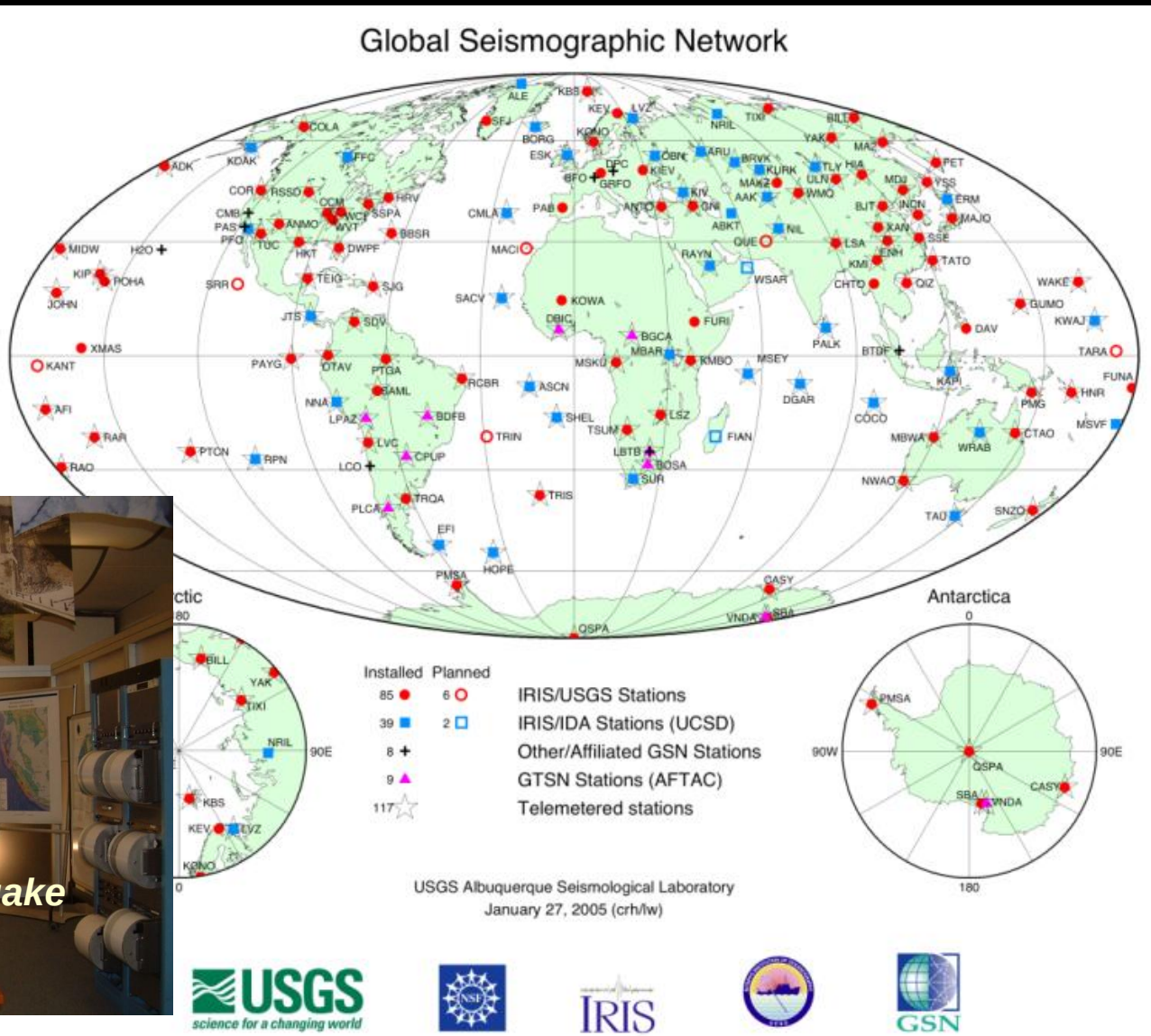
The USGS role in the National Earthquake Hazard Reduction Program partnership

- Provide earthquake monitoring and notifications,
- Assess seismic hazards,
- Conduct targeted research needed to reduce the risk from earthquake hazards nationwide, and
- Work with NEHRP agencies and many other partners to support public awareness of earthquake hazards and impacts.

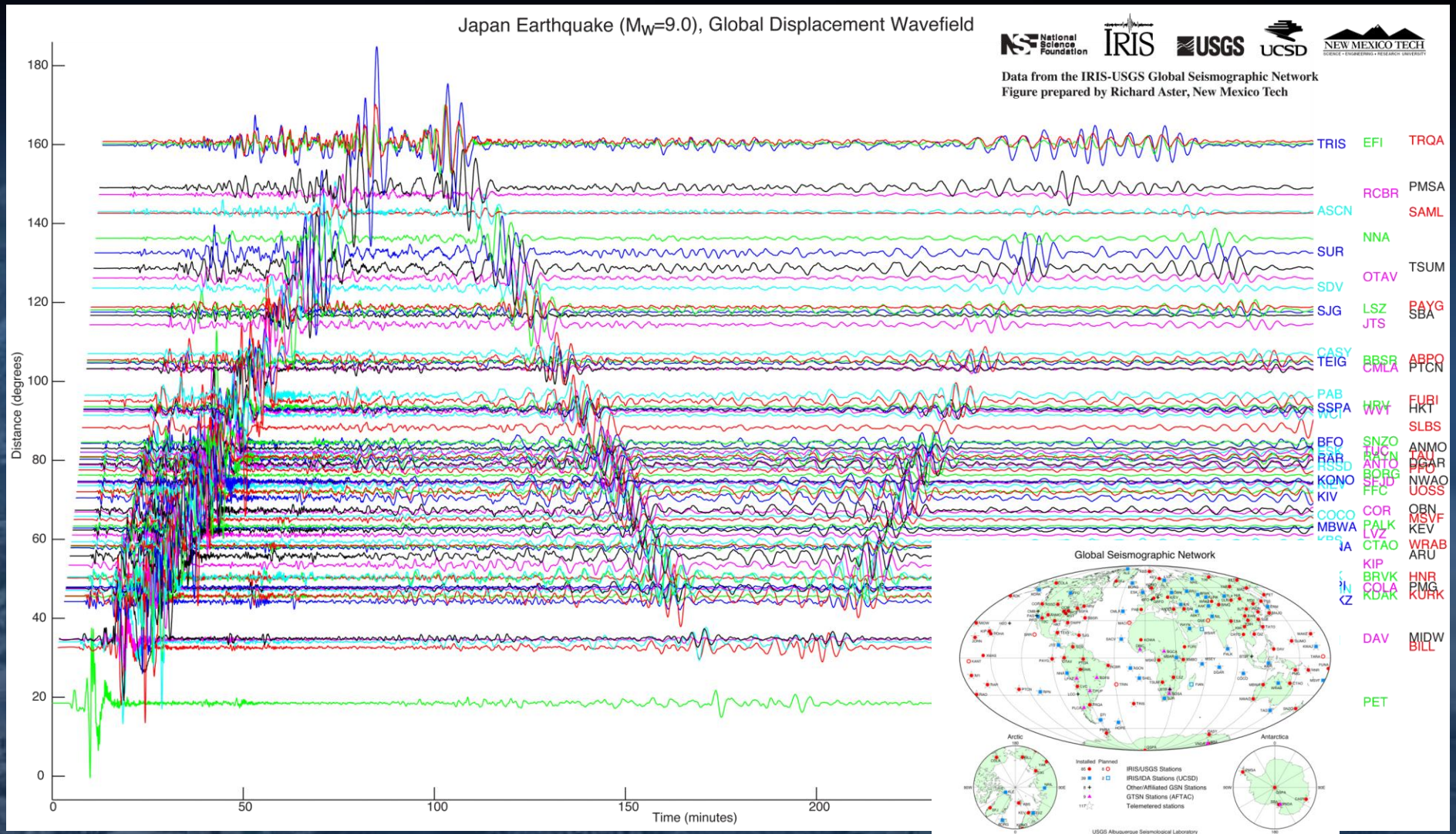


USGS provides rapid information on earthquakes worldwide

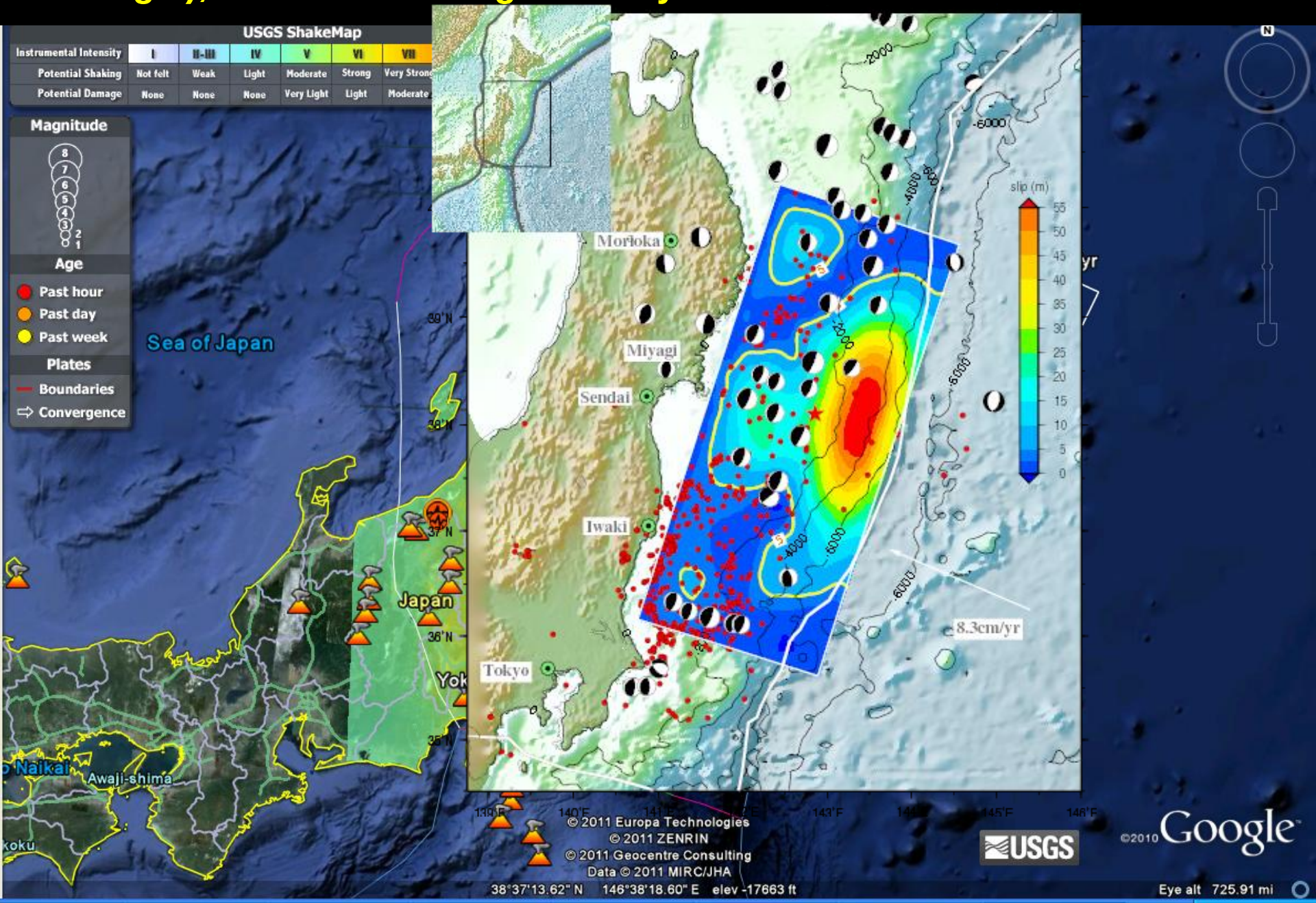
USGS *National Earthquake Information Center, Golden, Colorado*



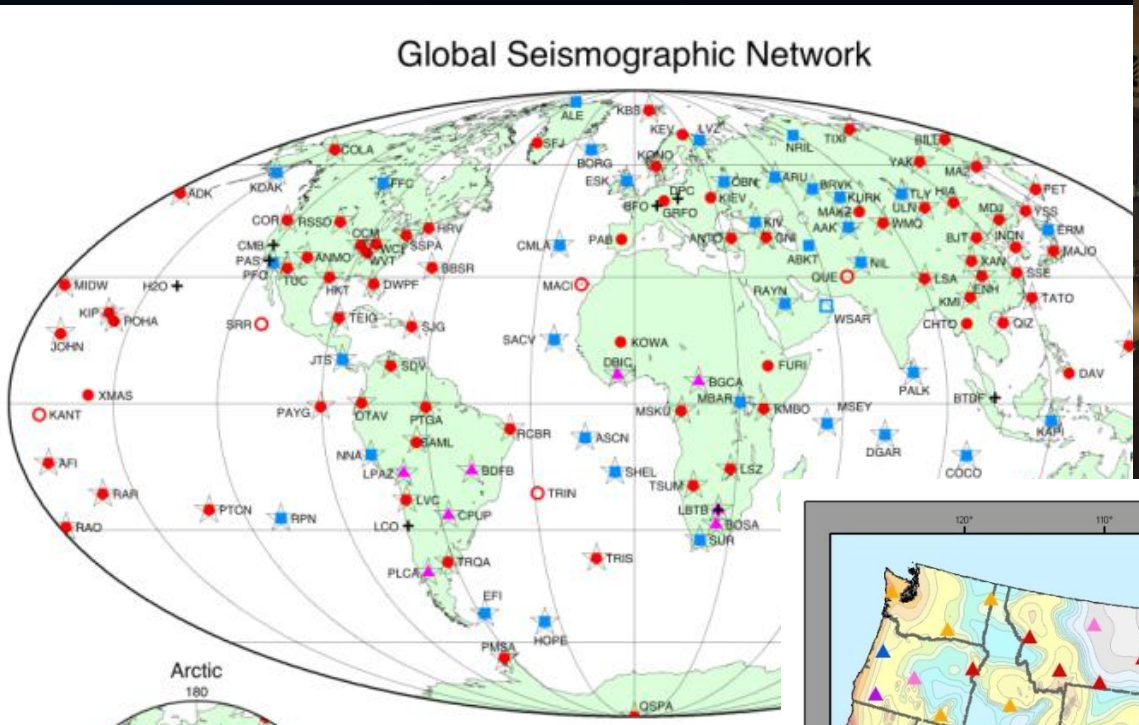
Giant earthquakes ring the Earth like a bell

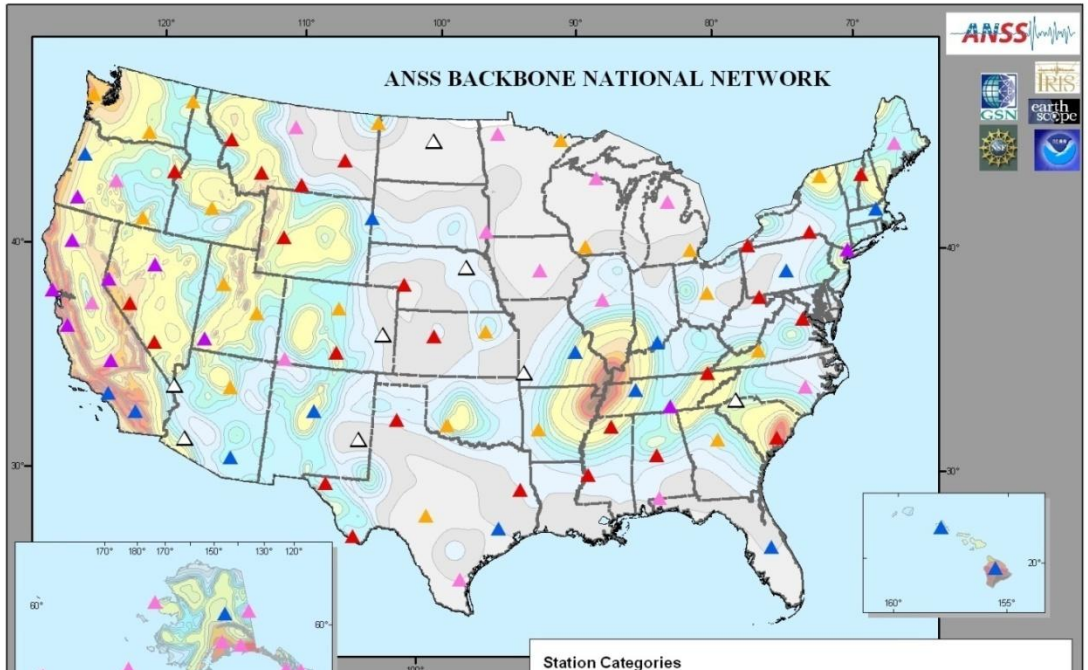


GoogleEarth feed from USGS showing fault rupture plane (blue rectangle), modeled shaking intensity and aftershocks



USGS provides rapid information on earthquakes worldwide





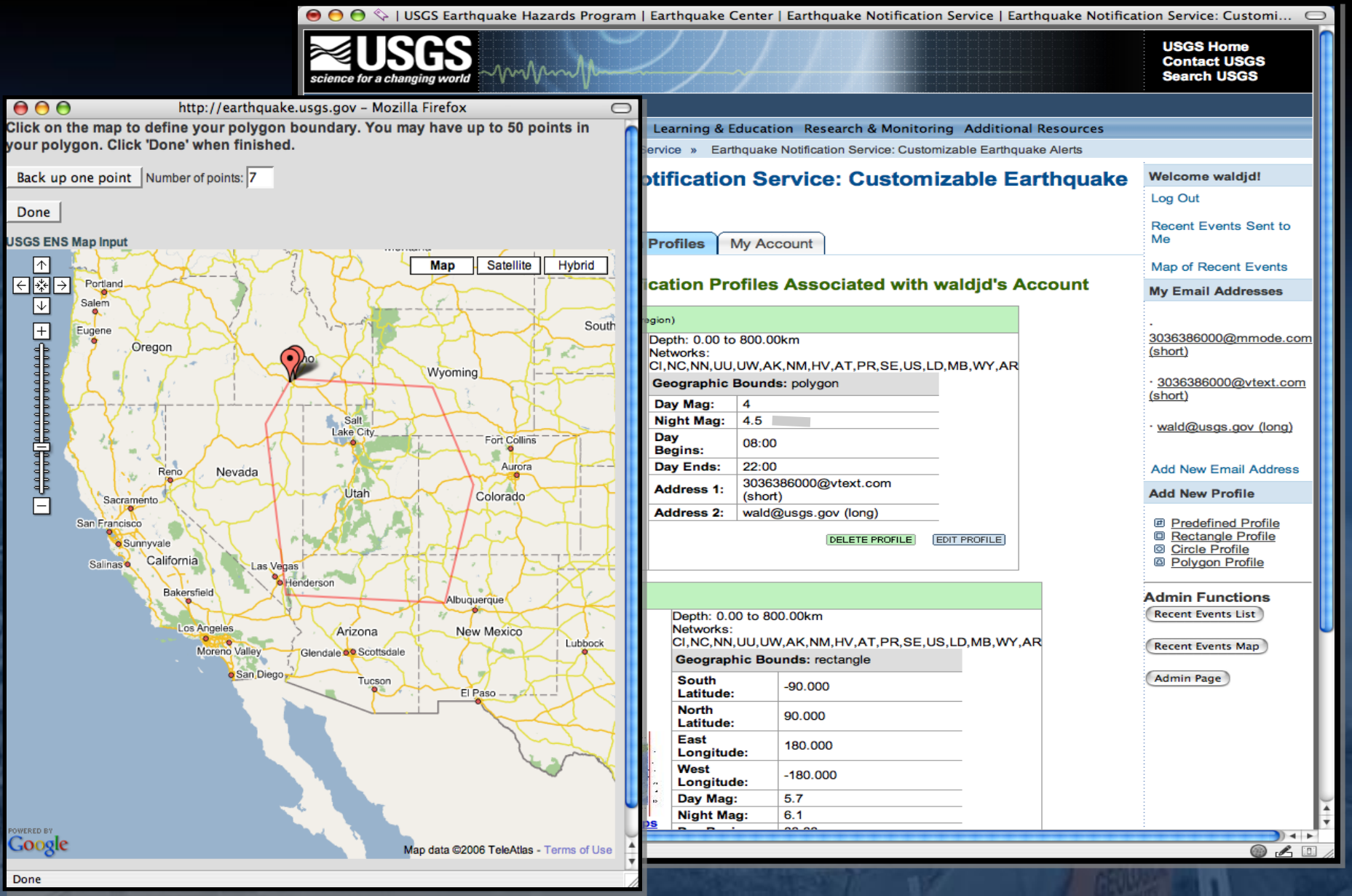
USGS Earthquake Notification System

Over 200,000 users

nehrp

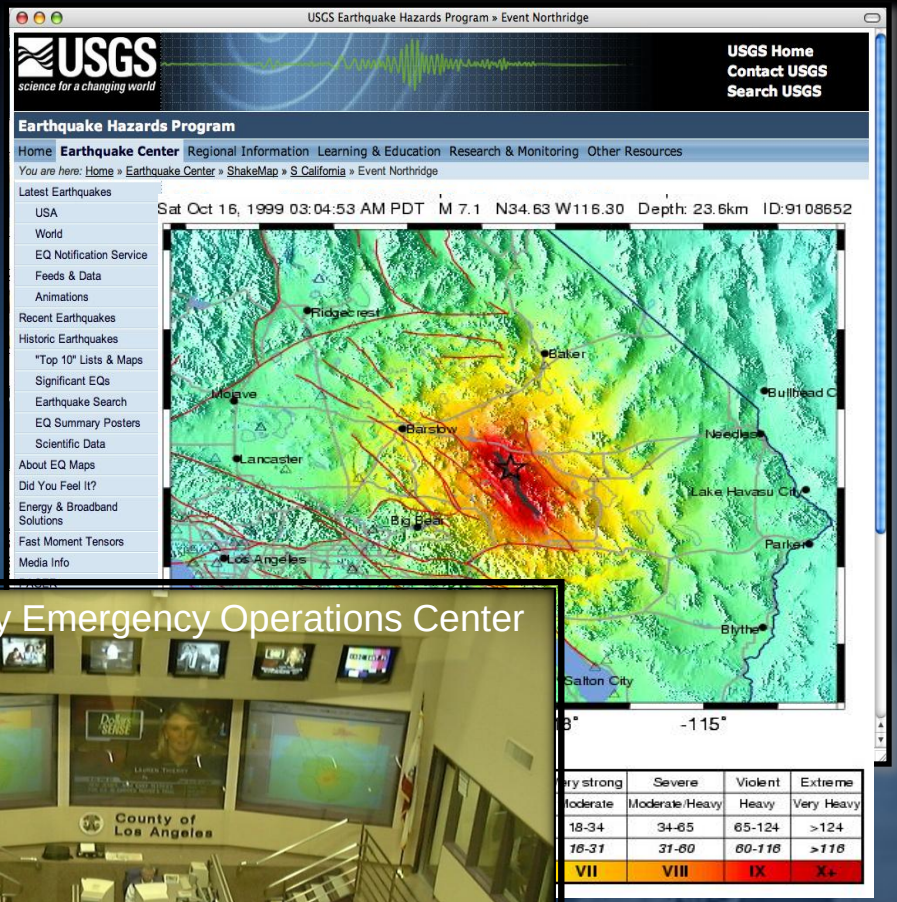
USGS

ENS can be customized to suit your needs



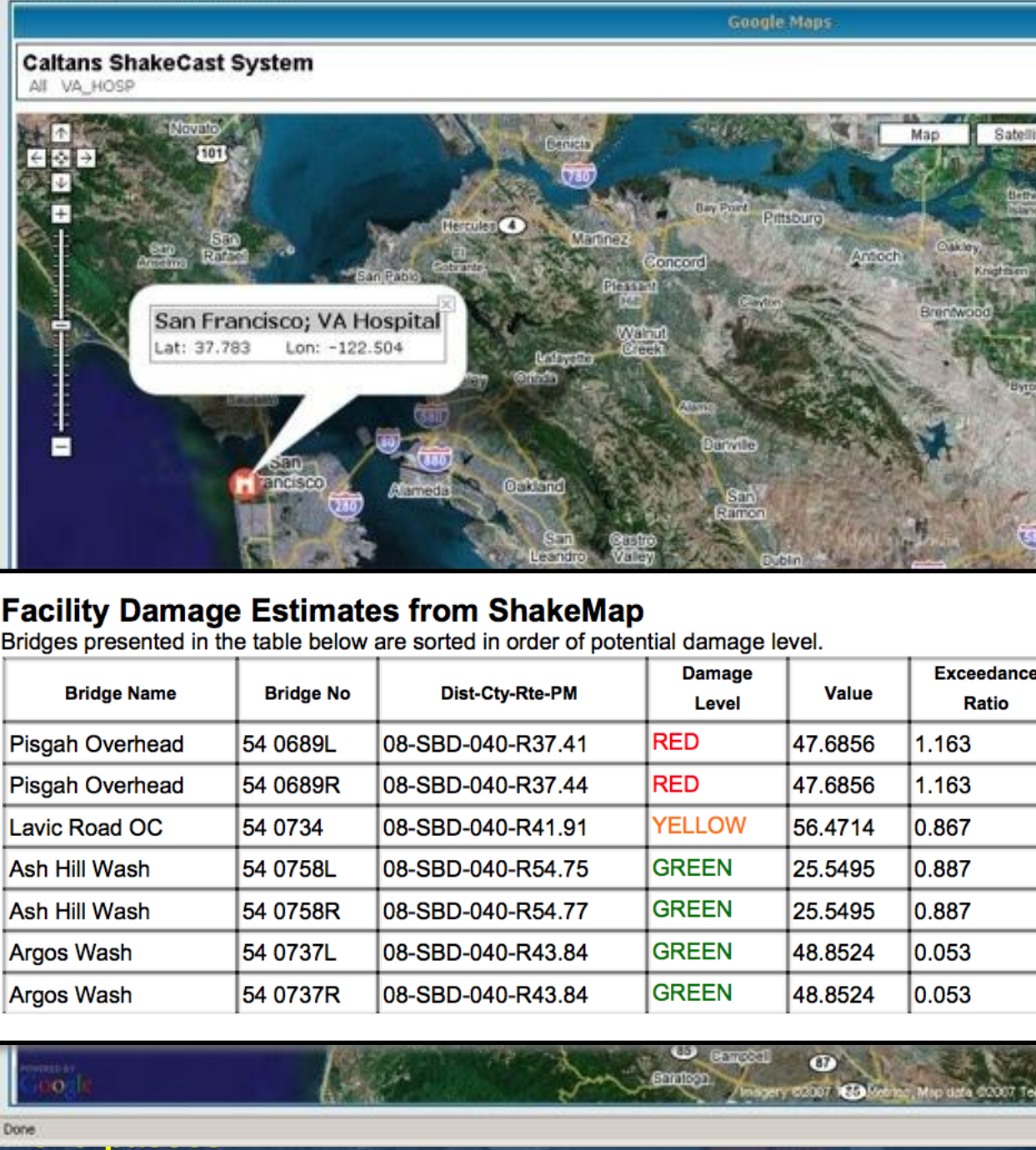
ShakeMap: A tool for rapid post-earthquake response, coordination, and situational awareness

California Governor Schwarzenegger pointing to ShakeMap at his press conference following the 2008 M5.4 Chino Hills earthquake that hit LA.



ShakeCast

Automated notifications to operators of critical facilities



Facility Damage Estimates from ShakeMap

Bridges presented in the table below are sorted in order of potential damage level.

Bridge Name	Bridge No	Dist-Cty-Rte-PM	Damage Level	Value	Exceedance Ratio
Pisgah Overhead	54 0689L	08-SBD-040-R37.41	RED	47.6856	1.163
Pisgah Overhead	54 0689R	08-SBD-040-R37.44	RED	47.6856	1.163
Lavic Road OC	54 0734	08-SBD-040-R41.91	YELLOW	56.4714	0.867
Ash Hill Wash	54 0758L	08-SBD-040-R54.75	GREEN	25.5495	0.887
Ash Hill Wash	54 0758R	08-SBD-040-R54.77	GREEN	25.5495	0.887
Argos Wash	54 0737L	08-SBD-040-R43.84	GREEN	48.8524	0.053
Argos Wash	54 0737R	08-SBD-040-R43.84	GREEN	48.8524	0.053

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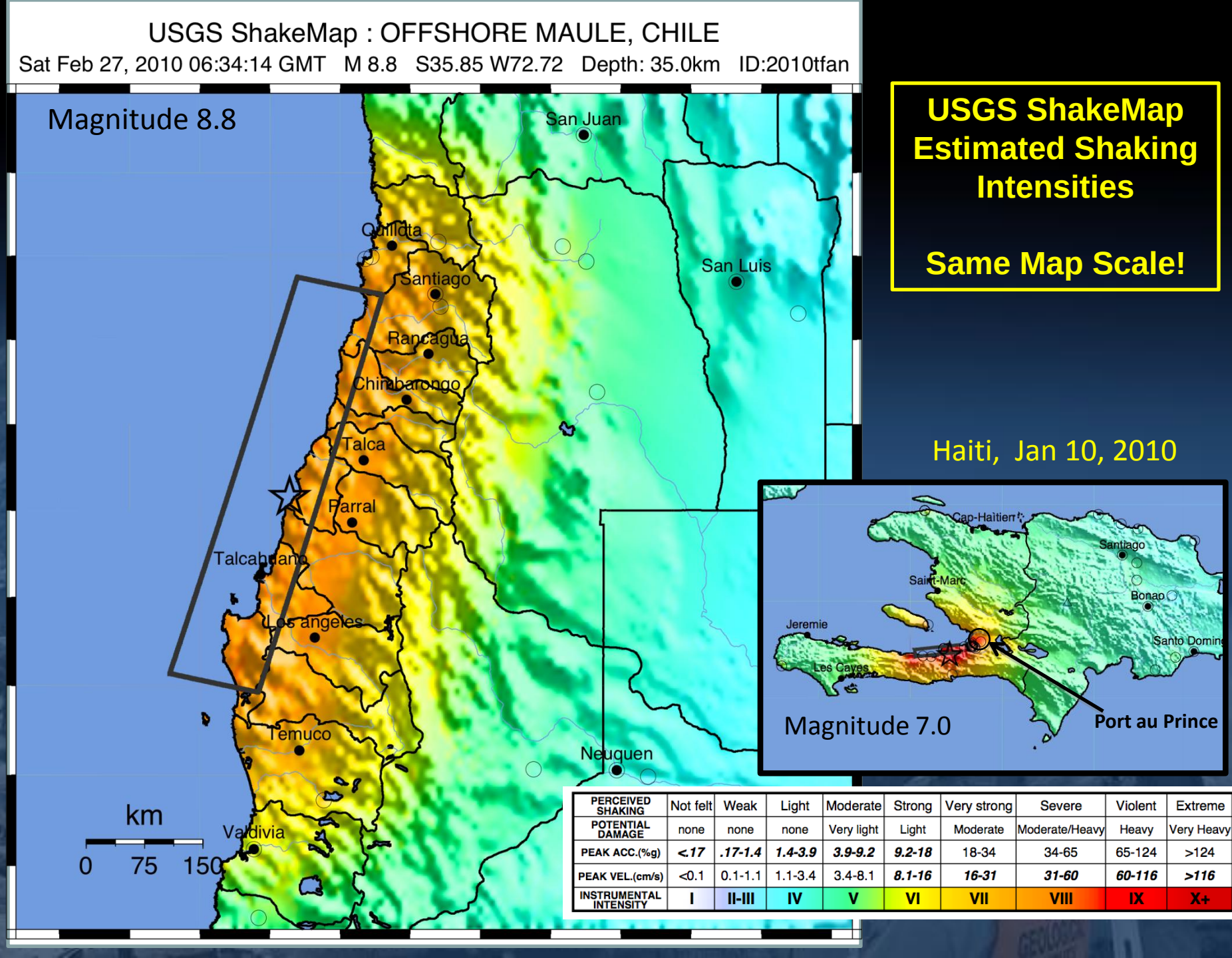
USGS ShakeMap : OFFSHORE MAULE, CHILE
Sat Feb 27, 2010 06:34:14 GMT M 8.8 S35.85 W72.72 Depth: 35.0km ID:2010tfan
Magnitude 8.8
San Juan
Quillota
Santiago
San Luis
Rancagua
Chimbarongo
Talca
Parral
Talcahuano
Los angeles
Temuco
Neuquen
Valdivia
km
0 75 150
USGS ShakeMap
Estimated Shaking
Intensities
Same Map Scale!
Haiti, Jan 10, 2010
Cap-Haitien
Santiago
Saint-Marc
Bonao
Jeremie
Les Cayes
Magnitude 7.0
Port au Prince
PERCEIVED SHAKING | Not felt | Weak | Light | Moderate | Strong | Very strong | Severe | Violent | Extreme
POTENTIAL DAMAGE | none | none | none | Very light | Light | Moderate | Moderate/Heavy | Heavy | Very Heavy
PEAK ACC.(%g) | <.17 | .17-1.4 | 1.4-3.9 | 3.9-9.2 | 9.2-18 | 18-34 | 34-65 | 65-124 | >124
PEAK VEL.(cm/s) | <0.1 | 0.1-1.1 | 1.1-3.4 | 3.4-8.1 | 8.1-16 | 16-31 | 31-60 | 60-116 | >116
INSTRUMENTAL INTENSITY | I | II-III | IV | V | VI | VII | VIII | IX | X+

Situational awareness available in 20 minutes

Prompt
Assessment of
Global
Earthquakes
for
Response

Rapidly estimated that over 2 million people were exposed to violent shaking

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M 7.0, HAITI REGION

Origin Time: Tue 2010-01-12 21:53:10 UTC
Location: 18.46°N 72.53°W Depth: 13 km

GSN USAID FROM THE AMERICAN PEOPLE

PAGER
Version 8

Created: 1 day, 20 hours after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	5,887k*	7,261k	1,049k	571k	314k	2,246k	332k
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

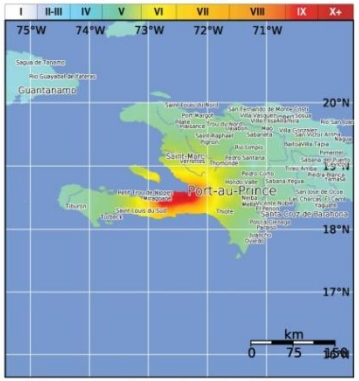
Selected City Exposure

MMI	City	Population
X	Grand Goave	5k
IX	**Port-au-Prince**	**1,235k**
IX	Carrefour	442k
IX	Petionville	108k
IX	Delmas 73	383k
IX	Croix des Bouquets	9k
VI	**Miragoane**	**6k**
V	**Verrettes**	**49k**
III	Santo Domingo	2,202k
III	**Guantanamo**	**273k**

bold cities appear on map (k = x1000)

Shaking Intensity

MMI



SAMPLE PAGER ALERT RECIPIENTS

The World Bank
IBRD & IDA: Working for a World F

China's earthquake emergency rescue center

USAID
FROM THE AMERICAN PEOPLE

MercyCorps
Be the change

Australian Government
Geoscience Australia

Associated Press

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

UPI.com
100 YEARS OF JOURNALISTIC EXCELLENCE

EERI
Earthquake Engineering Research Institute

GDACS
Global Disaster Alert & Coordination System

REUTERS

Aid Agencies/NGO

International

THE WHITE HOUSE
PRESIDENT GEORGE W. BUSH

ANSS

Federal Government

U.S. DEPARTMENT of STATE

FEMA

AIR FORCE TECHNICAL APPLICATIONS CENTER

USNORTHCOM
DEFENDING OUR HOMELAND

Homeland Security

US AIR FORCE

Office of Science and Technology Policy

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Earthquake Shaking — Red Alert

Summary Alert = greater of Econ/Fatal Alert Levels

GSN ANSS

AID FROM THE AMERICAN PEOPLE

M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)

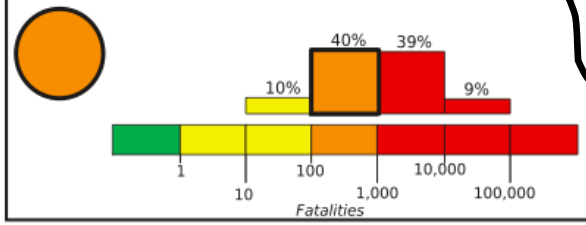
Location: 35.85°S 72.72°W Depth: 35 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 3

Created: 3 hours, 10 minutes after earthquake

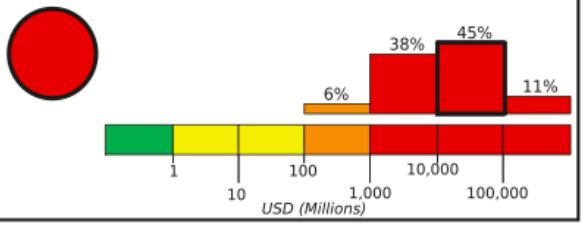
Estimated Fatalities



Orange alert level for shaking-related fatalities. Significant casualties are likely.

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

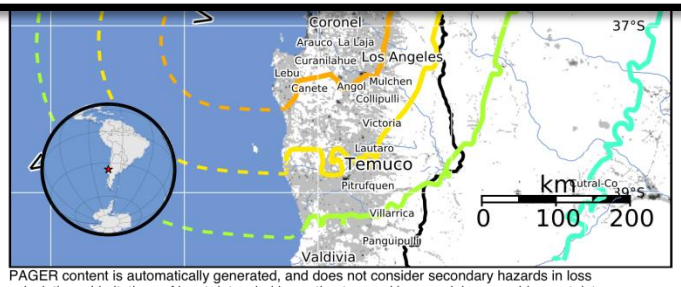
Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.



VIII	**Arauco**	**25k**
VIII	Lota	50k
VIII	**Concepcion**	**215k**
VIII	Constitucion	38k
VII	Bulnes	13k
VII	Cabrero	18k
VI	**Temuco**	**238k**
VI	**Valparaiso**	**282k**
VI	**Santiago**	**4,837k**
IV	Mendoza	877k
III	Neuquen	242k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/pager

Event ID: us2010tfan

Three red alerts; three very different outcomes for fatalities

USGS science for a changing world

Summary Alert: Red

USAID FROM THE AMERICAN PEOPLE

M 7.0, HAITI REGION

Origin Time: Tue 2010-01-12 21:53:10 UTC (16:53:10 local)
Location: 18.45°N 72.57°W Depth: 13 km

PAGER Version 1

Created: 1 month, 2 weeks after earthquake

Estimated Fatalities

Red alert for fatalities and economic losses. High casualties and widespread damage are likely and the disaster is potentially widespread. Past red alerts have required a national or international response.

Estimated Economic Losses

Estimated Population Exposed to Earthquake

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	50k*	7,272k*	6,149k	
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	S
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	
	Vulnerable Structures	none	none	none	Light	M

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 s

0 5 50 100 500 1000 5

230,000 fatalities; ~$6-9B losses

This information was automatically generated.
http://earthquake.usgs.gov/pager

USGS science for a changing world

Summary Alert: Red

USAID FROM THE AMERICAN PEOPLE

M 7.0, SOUTH ISLAND OF NEW ZEALAND

Origin Time: Fri 2010-09-03 16:35:46 UTC (04:35:46 local)
Location: 43.53°S 172.12°E Depth: 5 km

PAGER Version 5

Created: 7 hours, 10 minutes after earthquake

Estimated Fatalities

Red alert level for economic losses. Extensive damage is likely and the disaster is potentially widespread. Estimated economic losses are 1-10% GDP of New Zealand. Past events with this alert level have required a national or international level response.

Green alert level for fatalities. There is a low likelihood of casualties.

Estimated Economic Losses

Estimated Population Exposed to Earthq

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	147*	91k*	111
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V
PERCEIVED SHAKING		Not felt	Weak	Light	Moder
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Lig
	Vulnerable Structures	none	none	none	Ligh

*Estimated exposure only includes population within the map area.

Population Exposure

population

0 5 50 100 500 1000

0 fatalities; $2-4B losses

USGS science for a changing world

Earthquake Shaking: Red Alert

USAID FROM THE AMERICAN PEOPLE

ANSS

M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)
Location: 35.85°S 72.72°W Depth: 35 km
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 3

Created: 3 hours, 10 minutes after earthquake

Estimated Fatalities

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

0 5 50 100 500 1000 5000 10000

490 fatalities; ~$15-30B losses

Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are low-rise reinforced/confined masonry and adobe block construction.

Historical Earthquakes (with MMI levels):

Date	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1985-03-03	308	7.9	VIII(301k)	
1985-03-03	352	7.0	IX(174k)	
1985-03-03	313	7.9	VII(5,433k)	17

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Red Alert PAGER for the Tohoku earthquake issued in 42 minutes

USGS science for a changing world

Earthquake Shaking — Red Alert

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

M 8.9, NEAR THE EAST COAST OF HONSHU, JAPAN

Origin Time: Fri 2011-03-11 05:46:23 UTC (14:46:23 local)

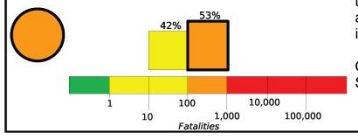
Location: 38.32°N 142.37°E Depth: 24 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 4

Created: 2 hours, 6 minutes after earthquake

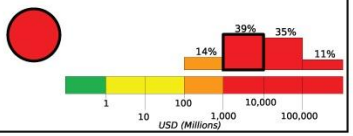
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of Japan. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses



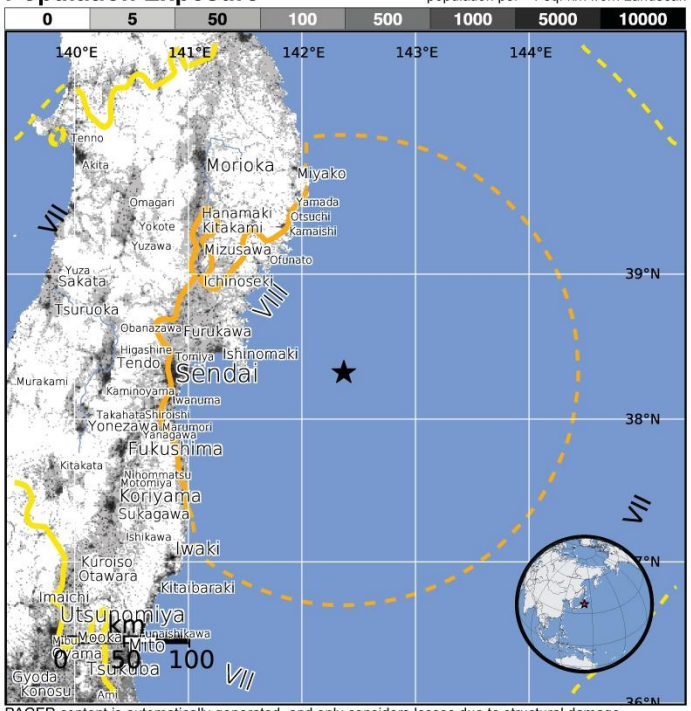
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	- -*	- -*	2,472k*	7,986k*	2,598k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan



Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are non-ductile reinforced concrete frame and heavy wood frame construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1998-06-14	363	5.7	VII(428k)	0
1994-12-28	263	7.7	VII(132k)	3
1983-05-26	369	7.7	VII(174k)	104

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and fires that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI	City	Population
VIII	**Ishinomaki**	**117k**
VIII	Shiogama	60k
VIII	Yamoto	32k
VIII	Kogota	20k
VIII	Rifu	35k
VIII	**Furukawa**	**76k**
VIII	Yamagata	255k
VII	**Morioka**	**295k**
VII	**Sendai**	**1,038k**
VII	**Fukushima**	**294k**
VII	**Utsunomiya**	**450k**

bold cities appear on map (k = x1000)

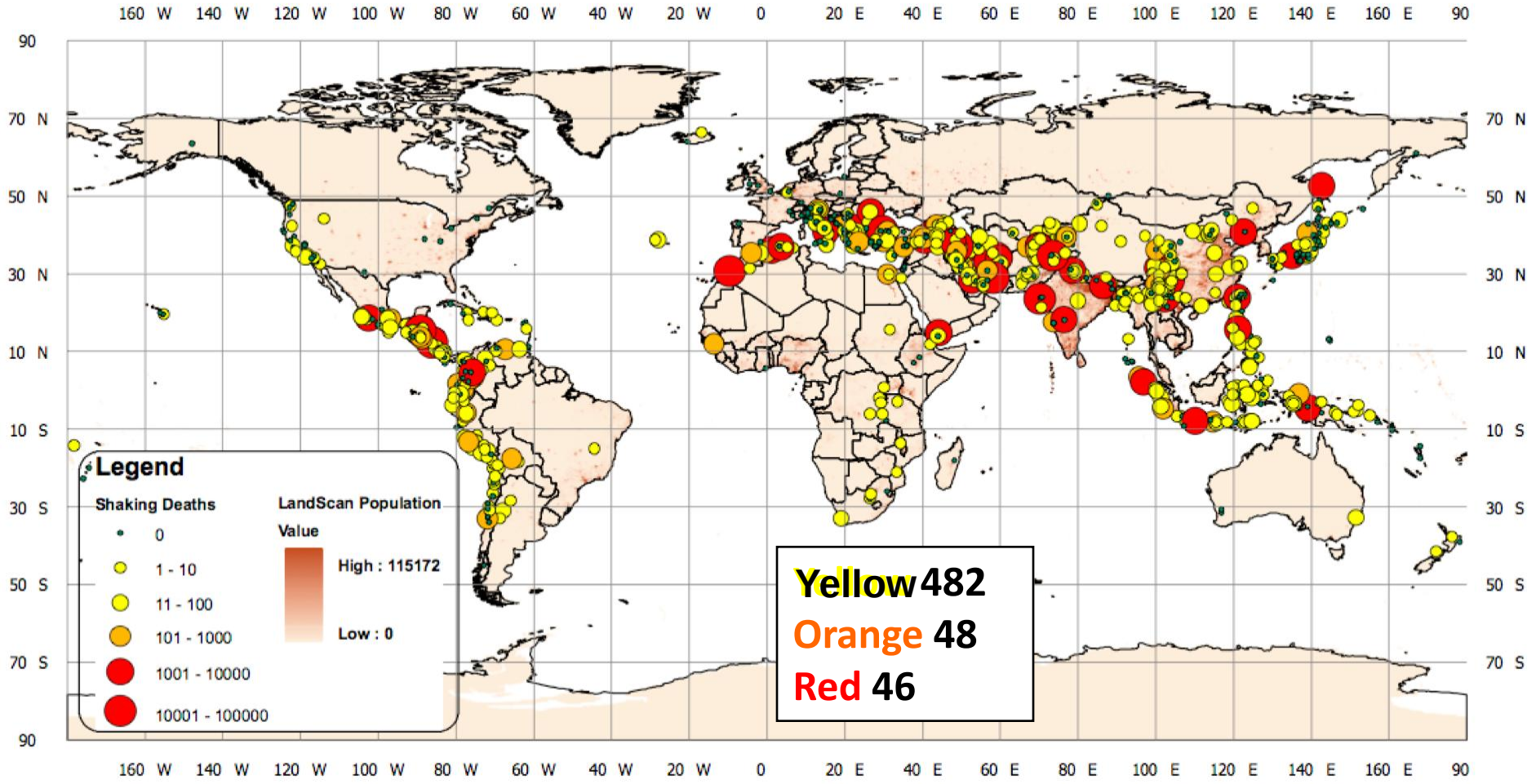
PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/pager

Event ID: usc0001xgp

USGS nehrp

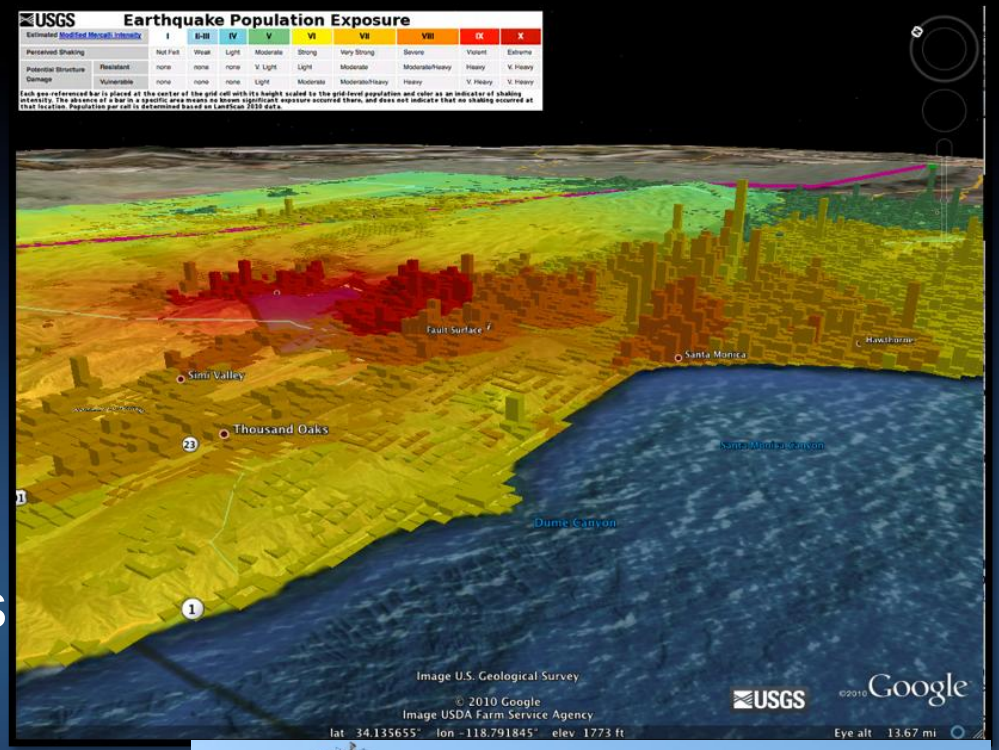
Global Fatality-based alerts over the past 40 years

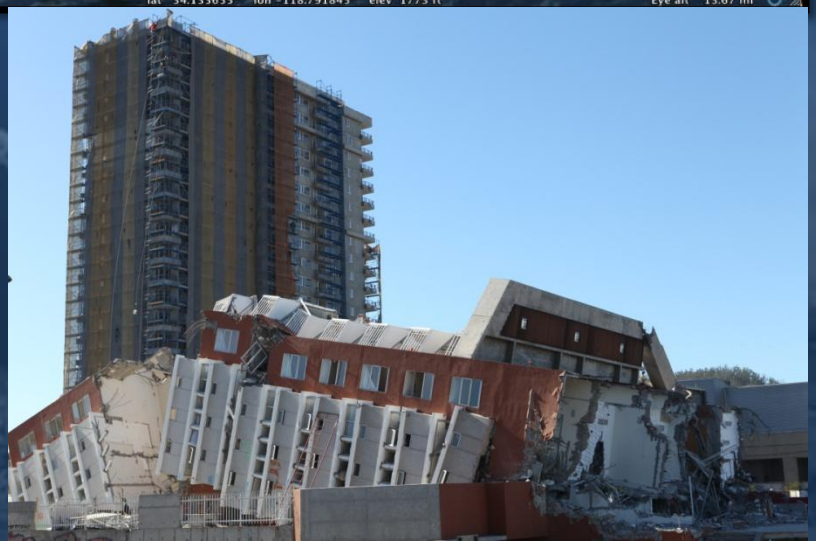


Map of fatality-based alert levels that would be triggered given the observed fatalities for events over the past forty years. The legend provides the fatality threshold for color-coded alert level. There would have been about 5,000 green, 490 yellow, 51 orange, and 48 red alerts (**approximately 12 yellow, 1-2 orange, and 1-2 red alerts per year**).

Future development of PAGER tools

- Develop strategies for estimating non-fatal casualties and displaced persons
- Generate loss estimates for scenario events
- Develop advanced 3-D zoomable visualization tools for PAGER impact information.
- Develop a global, country-specific building vulnerability index.





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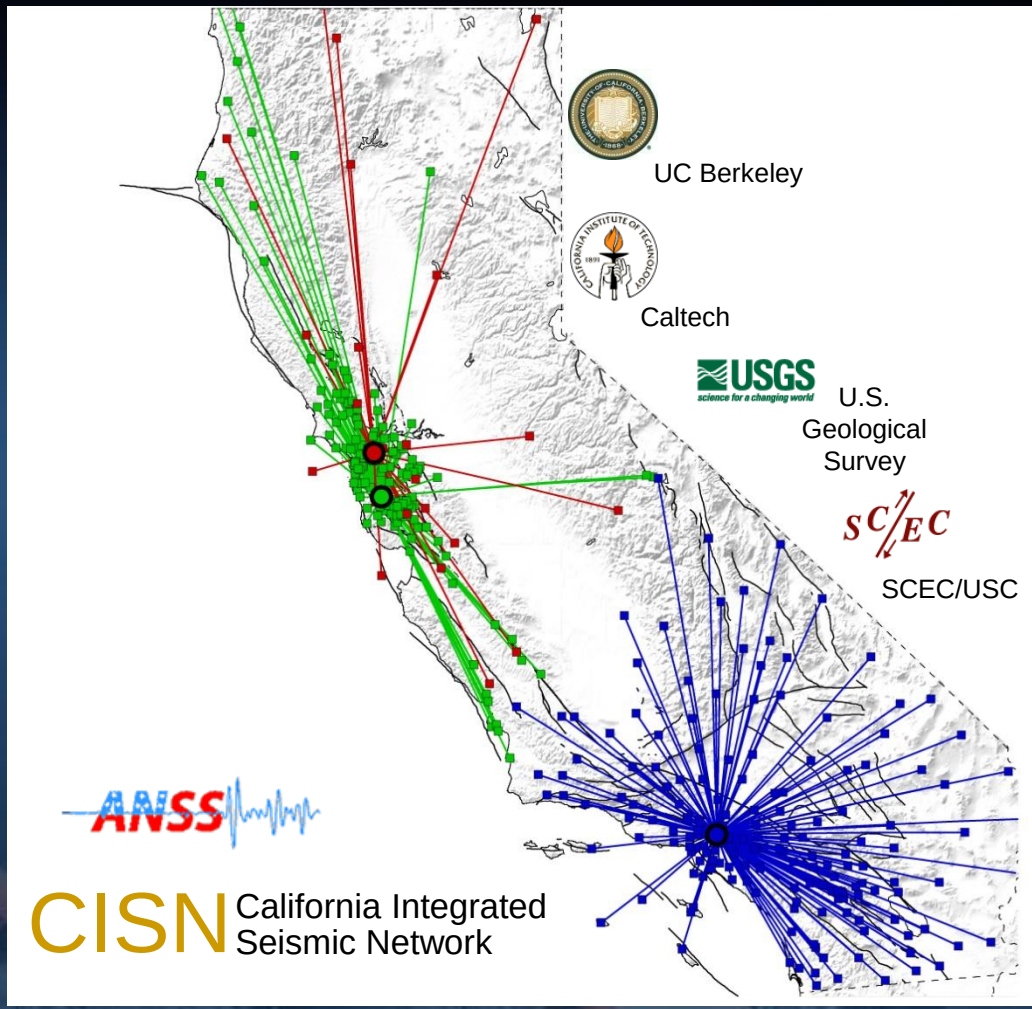
Japanese early warning systems

Automatic earthquake warning triggered by computer

USGS nehrp

Earthquake early warning – getting ahead of strong ground shaking

- USGS/CISN Phase I (2007-2009) cooperative agreement supported algorithm testing
- Phase II (2010-2012) supports prototype development and identifies test users
- ARRA funding used to reduce datalogger delays
- EEW requirements:
  - -- rapid earthquake detection
  - -- early magnitude estimation
  - -- ground shaking prediction
  - -- robust monitoring networks
  - -- well-defined user community



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USGS/USAID Earthquake Disaster Assistance Team

- Partnership between USGS and the USAID Office of Foreign Disaster Assistance (OFDA).
- Provides technical assistance, advice and capacity-building in earthquake-prone developing nations.
- Recent post-quake deployments include Indonesia, Malawi, and ongoing in Haiti.

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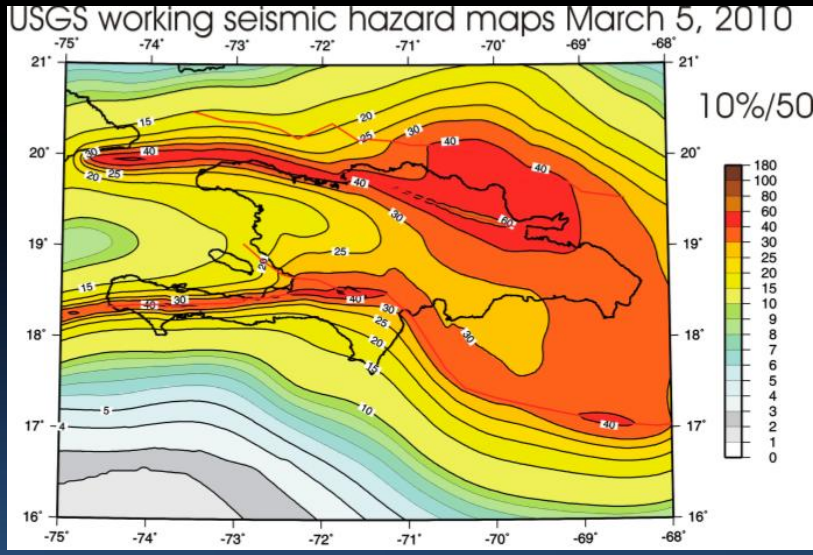
EDAT deployment in Haiti

- Temporary seismic station networks established
  - Port au Prince Urban Seismic Network for site-response analysis
  - Near-fault stations for aftershock detection
- Modern seismic hazard assessment for rebuilding
- Investigations of fault rupture and landslides
- Training

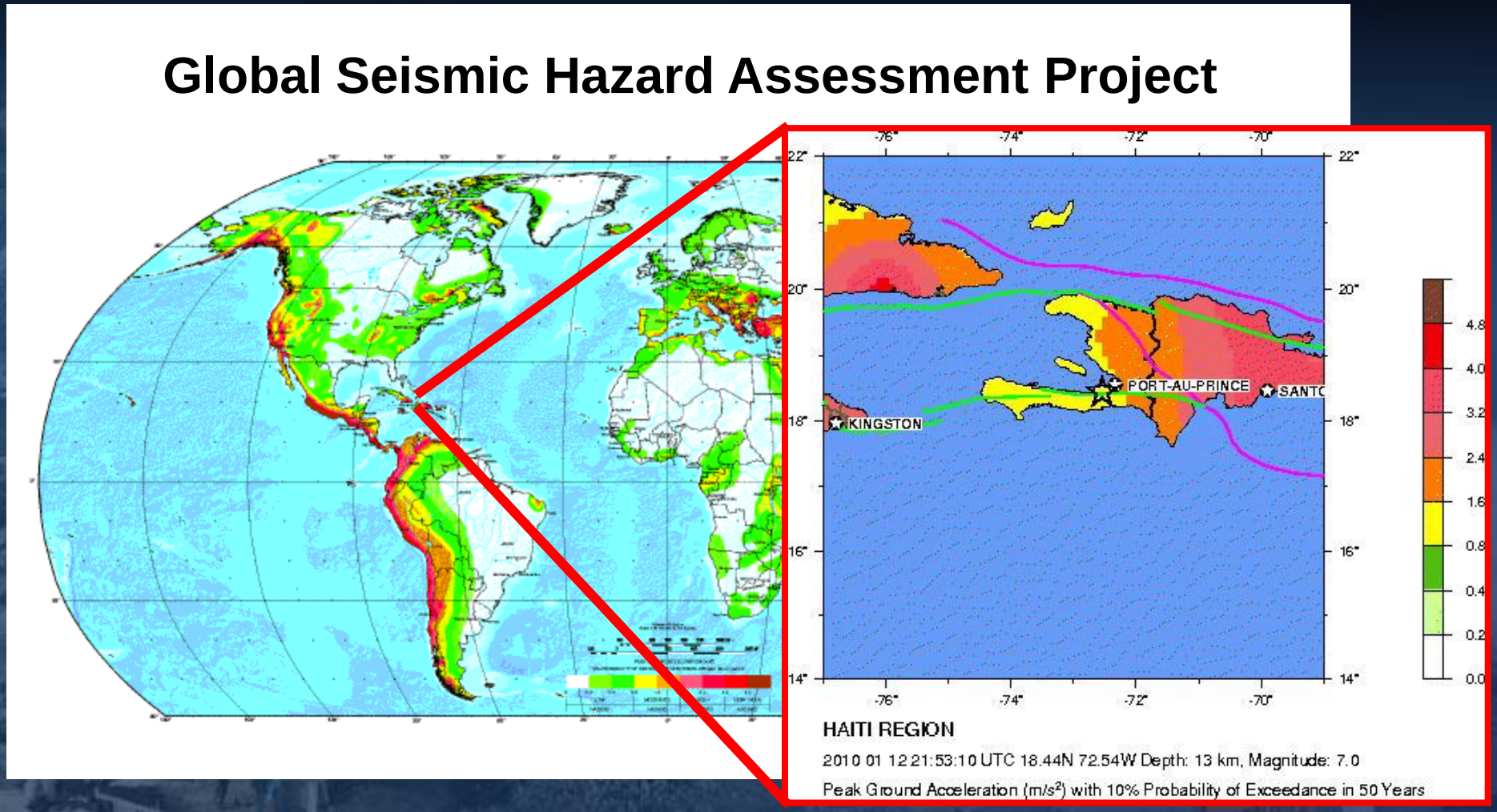


USGS and Haitian colleagues from Bureau of Mines and Energy installing station at school (Photo from Sue Hough, USGS)

USGS nehrp

USAID FROM THE AMERICAN PEOPLE

GSHAP: The current state of global seismic hazard assessment (same as it was in 1999)



PUBLIC PARTICIPANTS

Have formally adhered already (with financial contribution):


GERMANY


ITALY


SINGAPORE


NORWAY


SWITZERLAND


BELGIUM

Will hopefully adhere soon:


USA


TURKEY


INDIA


CHINA


FRANCE

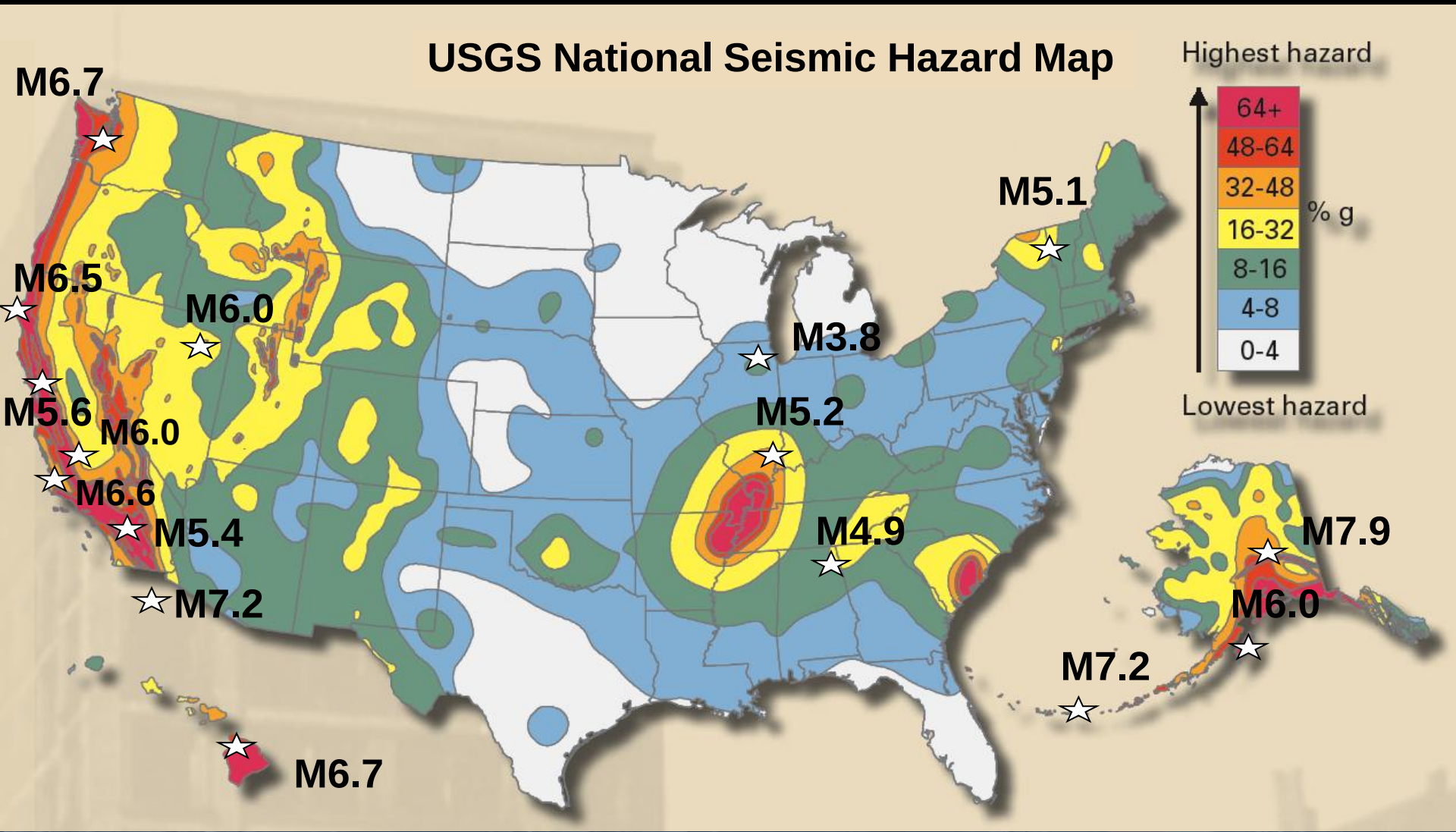

JAPAN

And then many others...

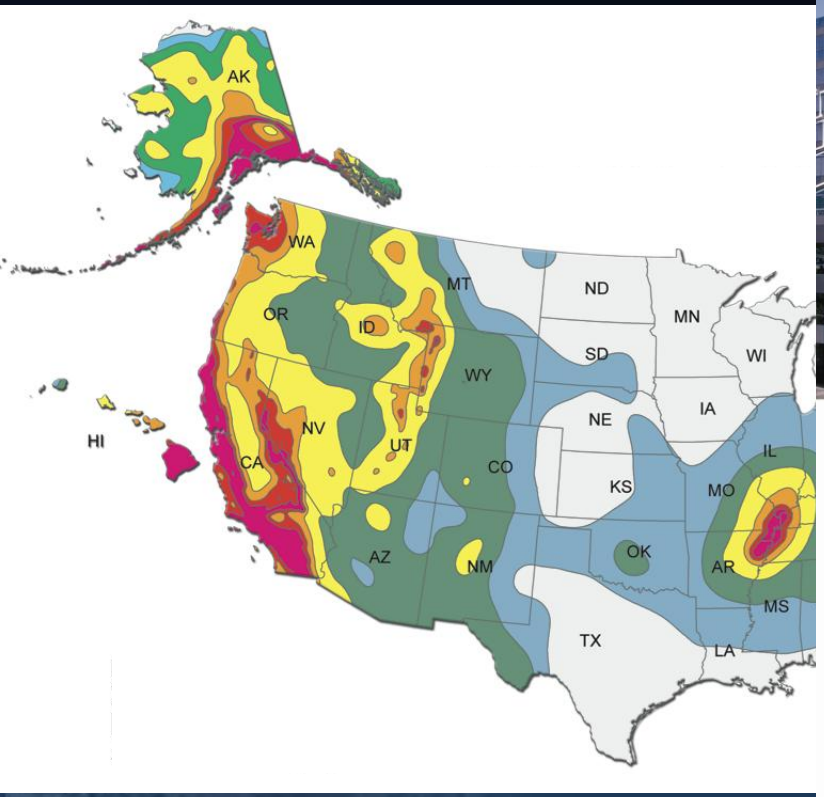
Russia, Australia, New Zealand, Nepal, Bangladesh, Portugal, Luxembourg, ..

From presentation by Rui Pinho, GEM Secretariat

Earthquakes are a national hazard



Translating USGS national hazard maps into model building codes



NEHRP Recommended Seismic Provisions
for New Buildings and Other Structures
FEMA P-750 / 2009 Edition

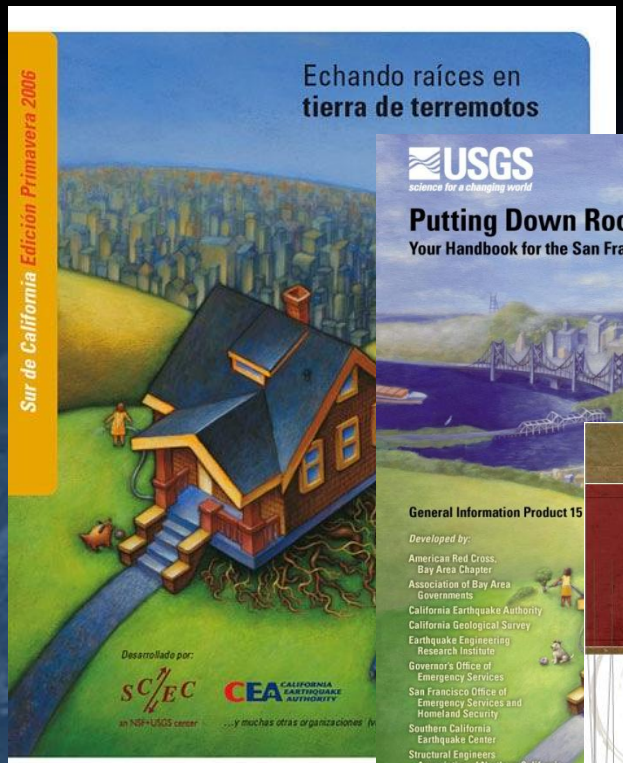
FEMA

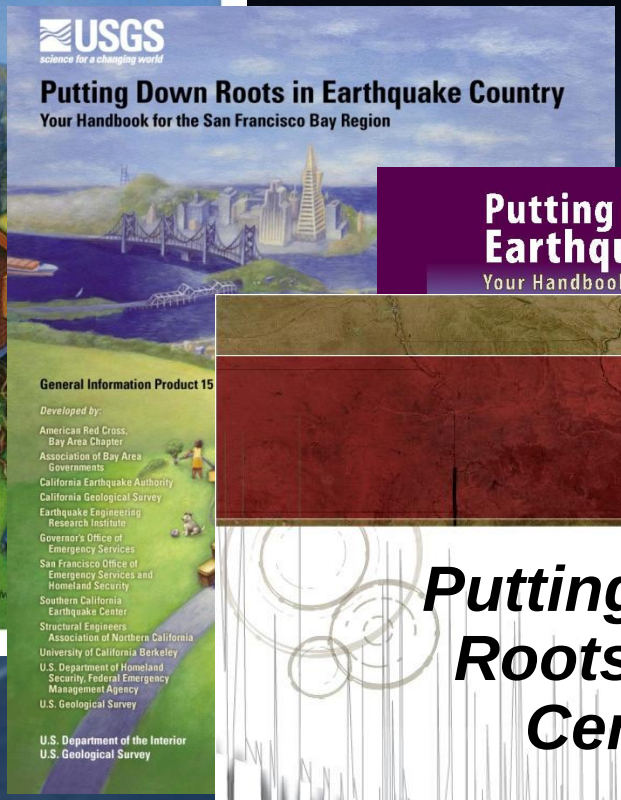
nehrp

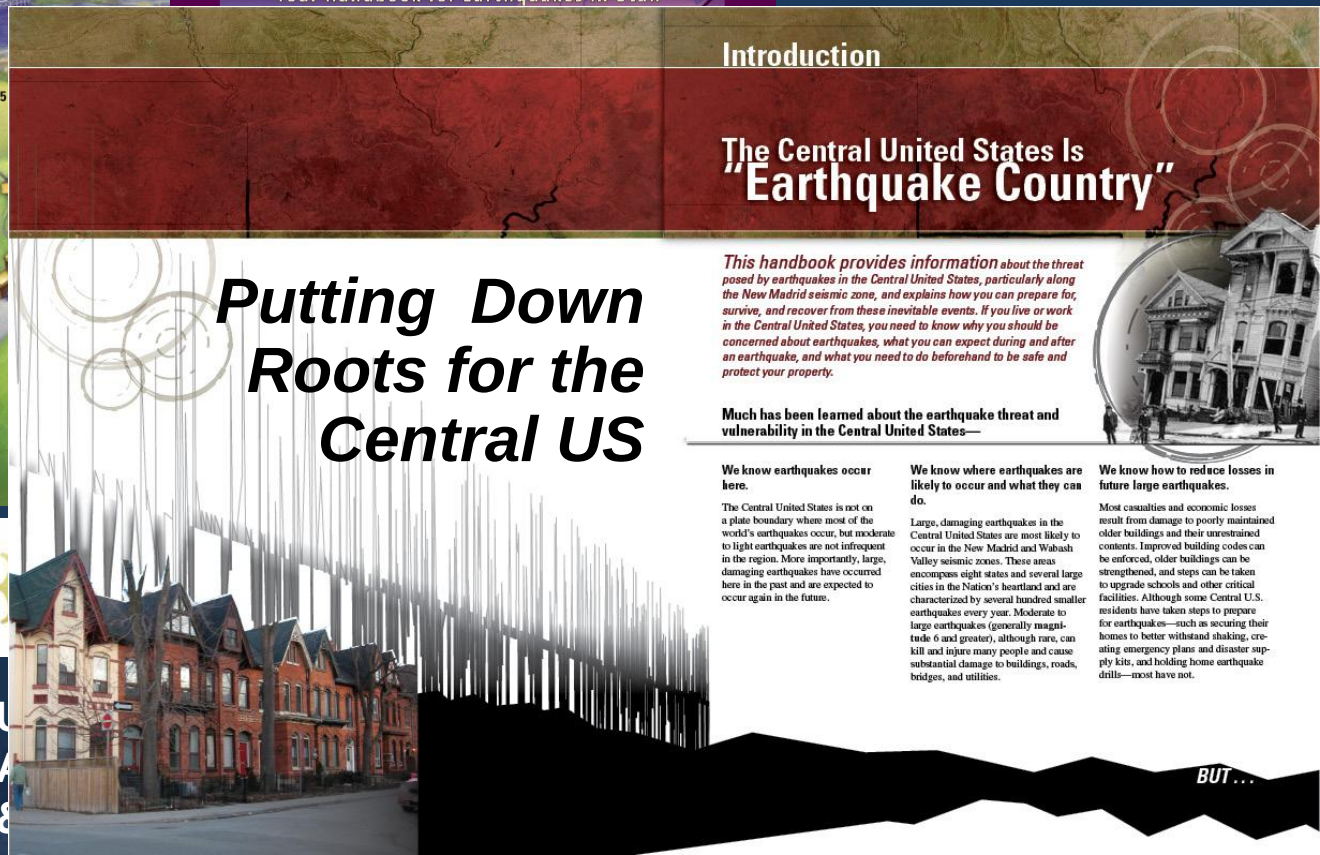
USGS nehrp

Seismic element of NEHRP Provisions and Int'l Building Code based on the USGS national seismic hazard map

Putting Down Roots in Earthquake Country







http://pubs.usgs.gov/gip/119/

FEMA

CEA CALIFORNIA EARTHQUAKE AUTHORITY

SCEC an NSF+USGS center

USGS science for a changing world

CGS CALIFORNIA GEOLOGICAL SURVEY

Welcome to the Great Central U.S. ShakeOut! | OTHER SHAKEOUTS | SEARCH: | GO

Be a Part of the ShakeOut
Register Now!
Log in

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GET READY TO SHAKEOUT!

Register now for the 2011 ShakeOut on April 28 at 10:15 a.m.!*

Participate in the Great Central U.S. ShakeOut to practice how to protect yourself during earthquakes, and to get prepared.

Learn how to participate below.

*Indiana will ShakeOut on April 19. Also, you can hold your drill at another time or day if best for your schedule.

Time to 2011 ShakeOut:
3 months, 7 days 21:35:48

ANNOUNCEMENTS

The Great Central U.S. ShakeOut is a linked event to NLE 2011

Who is Participating?

ShakeOut Resources: ShakeOut Drill Manuals, flyers, movies, and much more

Why Drop, Cover, and Hold On?

QUICK LINKS

How to plan your drill and get prepared:

Select your category...

Earthquake hazards in your state:

Select your state...

FAQ: Frequently Asked Questions

INTERACTIVE MAP

Over 2.4 million

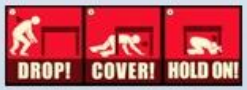
Participants and Counting!

Click the map for details about each state

Other Areas

LEARN & PLAY

PLAY BEAT THE QUAKE



QUAKE QUIZ

http://www.shakeout.org/centralus/

ARE YOU READY? | PREPARE | PROTECT | RECOVER

USGS

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Ready
Prepare. Plan. Stay Informed.®

American Red Cross

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science for a changing world

Any questions?

applegate@usgs.gov
703-648-6714

earthquake.usgs.gov

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